ORIGINAL ARTICLE

Inhalable Dust Exposure and Lung Function Among Rice Mill, Sawmill and Furniture Factory Workers

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ABSTRACT

Introduction: Exposure to total inhalable dust has become a public concern because constant exposure to the dust concentration exceeding workplace exposure limit may cause decline in lung function. This study aims to compare the total inhalable dust exposure among rice mill, sawmill, furniture factory and non-exposed workers as well as to correlate the dust exposure with lung function. **Methods:** A total of 77 exposed and 39 non-exposed workers were recruited into this study utilising purposive sampling method. The total inhalable dust concentration was collected using Institute of Occupational Medicine (IOM) personal airborne sampler loaded with glass microfibre filter connected to a sampling pump via tygon tubing which was attached to the workers. Post-shift lung function test was also measured. **Results:** There was a significant difference in the dust concentration between rice mill, sawmill, furniture factory and non-exposed workers ($p = 0.001$) with the highest median value of 2.4×10^3 µg/m^3 (IQR: $1.1 \times 10^3 - 5.8 \times 10^3$) among sawmill workers. Significant difference ($p = 0.001$) was shown between workers for measured forced expiratory value in one second (FEV1), measured forced expiratory value in one second and forced vital capacity ratio (FEV1/FVC) and predicted FEV1/FVC. Among the exposed workers, weak negative significant correlations were portrayed between total inhalable dust with the predicted forced vital capacity (FVC) ($r = -0.282$, $p = 0.013$) and predicted FEV1 ($r = -0.241$, $p = 0.035$). **Conclusion:** Dust concentration might be attributable to the lung function decline among exposed workers especially sawmill workers.

Keywords: Occupational exposure; Dust; Lung function

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INTRODUCTION

A number of respiratory diseases have been linked with exposure to inhalable organic dust. Working in dusty workplaces such as wood manufacturing and rice milling are associated with an increased prevalence of respiratory symptoms such as asthma, cough, eye and nose irritation as well as risk of chronic bronchitis (1 – 3). In addition to that, the wood pellet workers were reported to have more complaints on nasal symptoms, dry cough and asthma medication compared to control population (4). Whereas cough and breathlessness was more prevalent among sawmill workers in India (5). Similarly sawmill workers in Sulaimani City showed pulmonary function reductions and higher prevalence of pulmonary related symptoms (6). Sawmill workers who have a higher exposure towards total suspended and inhalable dust also have a high prevalence of cough and phlegm (7) which might be resulted from long duration of exposure to organic dust.

A previous study among sawmill workers had reported significant decrease in forced vital capacity (FVC), percentage of forced expiratory volume in one second (FEV_1), forced expiratory volume at 3% ($FEV_{3\%}$), maximal voluntary ventilation (MVV) and peak expiratory flow rate (PEFR) (5). Continuous exposure to wood dust has been associated with a significant decline (≥19%) in both obstructive and restrictive types of lung decline (6). Similarly, it has been reported that exposure to both cotton and wood dust have led to combined type of spirometric deficit revealing mixed obstructive and restrictive lung diseases (8). Despite no observed change during shift, workers have shown unexpected decline in lung function (FVC and FEV_1) (4). Based on a non-published study that was conducted at sawmill factories in Kelantan state of Malaysia, it was found that there was significant difference in pulmonary function test between the exposed and non-exposed sawmill workers (9). The reduction of FEV_1 and FVC resulted to restrictive impairment among exposed workers. Subjects are suspected with obstructive lung disorder if a low forced expiratory volume in one second and forced vital capacity ratio (FEV_1/FVC) is less than 70% whereas restrictive pattern is suspected when FEV_1/FVC is reduced to < 80% (10). The dearth of studies comparing the total inhalable dust exposure among different work settings has led to the design of the present study aiming to determine the relationship between personal exposure levels of total inhalable dust with the respiratory health among three different workers' group namely rice mill, sawmill and furniture factory workers; comparing with the non-exposed workers. The three groups were chosen because of the following reasons: i) rice is one of the major industries in Malaysia hence at risk of high exposure levels; ii) sawmill and furniture workers were proven to be at risk of respiratory diseases because of the dusty workplace and; iii) all three work settings produce high amount of dust.

MATERIALS AND METHODS

Study design and subject workers' recruitment

This was a comparative cross-sectional study recruiting a total of 116 subject workers utilising purposive sampling method, of whom 77 of them were workers exposed to organic dust at rice mill (n = 36), sawmill (n = 17) and furniture factories (n = 24). Non-exposed workers (n = 39) were recruited among administrative staff at the respective factories as well as from a university as they were unlikely to be exposed to dusty environment for more than eight hours. Subject workers who voluntarily agreed to participate had signed the informed consent form and were given questionnaire to gather their sociodemographic data. Ethical approvals for each population were obtained from the University's human ethical board (USM/JEPeM/14090312; USM/JEPeM/16120563; USM/JEPeM/17100543).

Total inhalable dust personal measurement

Personal airborne dust exposures were determined among subject workers following the Health and Safety Executive's Methods for the Determination of Hazardous Substances (MDHS) 14/4 guidance on general methods for sampling and gravimetric analysis of respirable, thoracic and inhalable aerosols (11). Total inhalable dust was collected using 25 mm in diameter Glass Fiber Filter (A) loaded into the IOM samplers connected to a pump (GilAir Plus Personal Air Sampling Pump, Sensidyne) by tygon tubing, operated at 2.0 litres/min. The IOM sampling head was clipped on the workers' collar around their breathing zone with the pump attached to their belt, for eight hours. The filters were pre-weighed and post-weighed, of which were left to equilibrate overnight (approximately 24 hours) for before and after sampling. The concentration of the dust converted into $\mu g/m^3$ was calculated following the equation provided in the MDHS 14/4 (11).

Lung function test

Lung function of the subject workers was measured using spirometer (COSMED Pony Fx desktop, Italy) after work shift. Prior to the test, the procedures were briefly explained and demonstrated to the subject workers, their personal details such as smoking habit, date of birth, height, weight, gender and race were keyed into the spirometer system. The subject workers were asked to put the mouthpiece into their mouth while clipping their nose. After taken in a deep breath and then while closing their lips tightly, they need to blow out through the mouthpiece into spirometer as hard, fast, smoothly and completely as possible. This process was repeated three times and the best blow or reading was recorded.

Data Analysis

The results were analysed using Statistical Packages for Social Sciences (SPSS) software version 24 at a significant level of $p < 0.05$. Descriptive data were analysed and presented for sociodemographics and work data, personal dust concentration and lung function test. Mann-Whitney test and Kruskal Wallis test were used to compare the exposure of total inhalable dust and lung function test between rice mill, sawmill, furniture factory and non-exposed control workers. The correlation of exposure to total inhalable dust and lung function was determined using Spearman's rank correlation test.

RESULTS

Sociodemographic data

Sociodemographic data is shown in Table I. Majority of the subject workers were male (n = 96, 82.8%) and Malay (n = 89, 76.7%) with average age of 38.1 ± 12.0 years old. Among the exposed workers, most of them have worked for nine years and below (n = 61, 79.2%) which were similar to the non-exposed workers (n = 28, 71.8%). Forty-four (57.1%) of exposed workers were smokers while only nine (23.1%) of non-exposed workers smoke cigarettes.

Total dust concentration

Table II shows the exposure of total inhalable dust concentration among rice mill, sawmill, furniture factory and non-exposed workers. Among exposed workers, sawmill workers had the highest median of personal dust exposure concentration of 2.4×10^3 $\mu g/m^3$ (IQR: 1.1×10^3 – 5.8×10^3) while furniture factory workers had the lowest median concentration, 1.0 $\mu g/m^3$ (IQR: 0.3 - 6.7). There was a significant difference of dust concentration level between the four groups (p = 0.001). Further assessment was made to compare the median dust concentration between rice mill, sawmill, furniture factory and non-exposed workers using Mann-Whitney test (Table III). There were significant differences of dust concentration between rice mill and furniture factory workers, rice mill and non-exposed workers, sawmill and furniture factory workers as well as sawmill and non-exposed workers, p = 0.001 respectively.

Lung function test

Table IV summarises the lung function test between rice mill, sawmill, furniture factory and non-exposed workers. Kruskal-Wallis test shows that there were significant differences in measured FEV_1 (p = 0.001) with rice mill workers having the lowest median 1.3 L (IQR: 1.3-1.8). Significant differences were also shown in measured FEV_1/FVC (p = 0.001) and predicted FEV_1/FVC (p = 0.001) where both rice mill (median: 45.0%, IQR: 45.9 – 62.9) and sawmill workers (median: 79.0%, IQR: 77.9 – 80.7) having the lowest percentage median, respectively.

Then, further test was done to eliminate the confounding factors as illustrated in Table V. Only male and non-smoking workers were compared for difference in lung function and it was found that measured FEV_1 (p = 0.001), measured FEV_1/FVC (p = 0.001), and predicted FEV_1/FVC (p = 0.010) showed significant difference among workers.

Table I : Sociodemographic data of rice mill, sawmill, furniture factory and non-exposed workers

Sociodemographic	Exposed Workers			Exposed n = 77	Non-exposed n = 39	Total N = 116
	Rice Mill n = 36	Sawmill n = 17	Furniture Factory n = 24			
Gender (N, %)						
Male	35 (97.2%)	17 (100.0%)	19 (79.2%)	71 (92.2%)	25 (64.1%)	96 (82.8%)
Female	1 (2.8%)	0 (0.0%)	5 (20.8%)	6 (7.8%)	14 (35.9%)	20 (17.2%)
Race						
Malay	22 (61.1%)	13 (76.5%)	21 (87.5%)	56 (72.7%)	33 (84.6%)	89 (76.7%)
Chinese	1 (2.8%)	1 (5.9%)	2 (8.3%)	4 (5.2%)	6 (15.4%)	10 (8.6%)
Indian	1 (2.8%)	0 (0.0%)	1 (4.2%)	2 (2.6%)	0 (0.0%)	2 (1.7%)
Others	12 (33.3%)	3 (17.6%)	0 (0.0%)	15 (19.5%)	0 (0.0%)	15 (12.9%)
Age (Years)						
Mean ± SD	35.9 ± 13.0	42.2 ± 14.6	37.1 ± 10.0	37.7 ± 12.6	39.1 ± 10.9	38.1 ± 12.0
Median (IQR)	33.5 (31.5-40.3)	45.0 (34.7-49.7)	37.5 (32.9-41.4)	37.0 (34.8-40.5)	34.0 (35.5-42.6)	35.5 (35.9-40.4)
Years Employed						
0-9	29 (80.6%)	9 (52.9%)	23 (95.8%)	61 (79.2%)	28 (71.8%)	89 (76.7%)
10-19	4 (11.1%)	4 (23.5%)	1 (4.2%)	9 (11.7%)	7 (17.9%)	16 (13.8%)
20-29	2 (5.6%)	3 (17.6%)	0 (0.0%)	5 (6.5%)	2 (5.1%)	7 (6.0%)
30-39	1 (2.8%)	1 (5.9%)	0 (0.0%)	2 (2.6%)	2 (5.1%)	4 (3.4%)
Smoking status						
No	7 (19.4%)	5 (29.4%)	14 (58.3%)	26 (33.8%)	30 (76.9%)	56 (48.3%)
Yes	24 (66.7%)	12 (70.6%)	8 (33.3%)	44 (57.1%)	9 (23.1%)	53 (45.7%)
Ex-smoker	5 (13.9%)	0 (0.0%)	2 (8.3%)	7 (9.1%)	0 (0.0%)	7 (6.0%)

Table II : Comparison of total dust concentration between rice mill, sawmill, furniture factory and non-exposed workers

Subject Workers	n	Total dust concentration (µg/m³) Median (IQR)	p-value
Rice Mill	36	1.1×10^3 ($0.9 \times 10^3 – 2.1 \times 10^3$)	0.001*
Sawmill	17	2.4×10^3 ($1.1 \times 10^3 – 5.8 \times 10^3$)	
Furniture Factory	24	1.0 (0.3-6.7)	
Non-exposed	34	0.5 (0.1 – 2.8×10^2)	

*Significance difference at p<0.05; statistical test – Kruskal Wallis test

Table III : Comparison of median dust concentration between rice mill, sawmill, furniture factory and non-exposed workers

Subject workers		Rice Mill	Sawmill	Furniture Factory
Sawmill	p-value	0.120		
Furniture Factory	p-value	0.001*	0.001*	
Non-exposed	p-value	0.001*	0.001*	0.607

*Significance difference at p<0.05; statistical test – Mann-Whitney test

Correlation between concentration of dust and lung function test

Correlation between concentration of dust and lung function test among exposed and non-exposed workers were tabulated in Table 6. Among exposed workers, there were weak negative significant correlations between concentration of personal dust exposure with FVC predicted (r = -0.282, p = 0.013), FEV_1 predicted (r = -0.241, p = 0.035) and strong positive significant correlation of FEV1/FVC predicted (r = 0.879, p = 0.018). Similarly, significantly negative but strong correlation was found between dust concentration and FVC predicted (r = -0.514, p = 0.02) among non-exposed. Moderate and positive strong correlation were shown for non-exposed group, between concentration of dust and FEV1/FVC measured (r = 0.394, p = 0.021) and predicted (r = 0.545, p = 0.001), respectively.

Table IV : Lung function test between rice mill, sawmill, furniture factory and non-exposed workers.

Workers	Median FVC (L) (IQR)		Median FEV1 (L) (IQR)		Median FEV1/FVC (%) (IQR)	
	Measured	Predicted	Measured	Predicted	Measured	Predicted
Rice Mill	2.9 (2.6-3.1)	3.9 (3.4-3.9)	1.3 (1.3-1.8)	3.3 (2.9-3.3)	45.0 (45.9-62.9)	81.0 (80.3-84.6)
Sawmill	2.4 (2.1-3.1)	4.26 (3.1-4.5)	2.1 (1.43-2.29)	3.4 (2.6-3.7)	81.0 (59.4-83.9)	79.0 (77.9-80.7)
Furniture Factory	2.8 (2.7-3.0)	3.82 (3.5-4.2)	2.2 (2.1-2.4)	3.2 (2.9-3.5)	80.5 (71.7-85.2)	80.0 (79.1-81.1)
Non-exposed	2.8 (2.5-2.8)	3.55 (3.3-3.9)	2.32 (2.0-2.7)	3.1 (2.9-3.6)	83.0 (77.9-87.4)	81.5 (81.9-86.4)
p-value	0.631	0.537	0.001*	0.818	0.001*	0.010*

*Significant difference at p<0.05; statistical test – Kruskal Wallis Test

Table V : Lung function test between rice mill, sawmill, furniture factory and non-exposed workers (controlled for confounders: gender and smoking habit)

Workers	Median FVC (L) (IQR)		Median FEV1 (L) (IQR)		Median FEV1/FVC (%) (IQR)	
	Measured	Predicted	Measured	Predicted	Measured	Predicted
Rice Mill	2.5 (2.0 – 3.9)	4.0 (1.9 – 4.5)	1.0 (0.5 – 3.0)	3.3 (1.4 – 3.9)	45.0 (26.0 – 93.0)	80.0 (74.0 – 89.0)
Sawmill	1.6 (1.2 – 4.2)	4.4 (3.0 – 5.2)	1.4 (1.0 – 2.8)	3.4 (2.5 – 4.4)	88.0 (65.0 – 94.0)	79.0 (76.0 – 83.0)
Furniture Factory	2.8 (2.4 – 3.6)	4.0 (2.4 – 5.2)	2.2 (1.7 – 2.7)	3.3 (2.0 – 4.4)	77.0 (49.0 – 97.0)	79.0 (78.0 – 83.0)
Non-exposed	2.9 (1.8 – 3.3)	4.4 (1.7 – 5.6)	2.4 (1.0 – 7.6)	3.8 (2.6 – 7.1)	83.0 (29.0 – 99.0)	81.0 (78.0 – 89.0)
p-value	0.205	0.512	0.001*	0.222	0.002*	0.048

*Significant difference at p<0.05; statistical test – Kruskal Wallis Test

Table VI : Correlation between concentration of dust and lung function test among exposed and non-exposed workers, respectively

Lung Function Test		Concentration total dust (μg/m³)	
		Exposed (n=77)	Non-exposed (n=39)
FVC measured	p-value	0.535	0.490
	r	-0.072	-0.340
FVC predicted	p-value	0.013*	0.02*
	r	-0.282	-0.514
FEV1 measured	p-value	0.536	0.908
	r	-0.072	-0.021
FEV1 predicted	p-value	0.035*	0.092
	r	-0.241	-0.294
% FEV1/FVC measured	p-value	0.571	0.021*
	r	-0.066	0.394
% FEV1/FVC predicted	p-value	0.018*	0.001*
	r	0.879	0.545

*Significant difference at p<0.05; statistical test – Spearman Rho Correlation

DISCUSSION

Workplace dust level

In Malaysia, studies evaluating dust exposure among exposed workers have been carried out in wooden furniture industry (12), steel mill industry (13), mineral dust (14), cement industry (15) and paper-based mills (16). This current study provides comparative data of total inhalable personal dust exposure in four different workplace settings associated with the lung function test. Our findings show significant difference in the dust concentration between rice mill, sawmill, furniture factory and non-exposed workers ($p = 0.001$) as well as between exposed and non-exposed workers. Health and Safety Executive (HSE) has set the Workplace Exposure Limit (WEL) at 5 mg/m³ (5.0 x 10^3 μg/m³) for inhalable wood dust (17) while level exposure to grain should not exceed 10 mg/m³ (18) (10 x 10^3 μg/m³). The permissible exposure limit for inhalable dust based on the American Conference of Governmental Industrial Hygienists (ACGIH) standard is 10 mg/m³. When comparing the findings of the current study with the WEL, our finding for the level in sawmill industry (2.4 x 10^3 μg/m³) does not exceed the standard level. This contrasted with previous studies of Osuchukwu and colleagues (19) in Nigeria where a large portion of the workers were exposed to inhalable dust exceeding the permissible limit because they worked for more than eight hours per day. In addition to that, Osman and Pala (20) had conducted a study among 328 woodworkers from furniture industry in Bursa/Turkey estate and found that 9.5% of them were exposed to saw dust beyond the WEL. Another study (21) conducted in Costa Rica among 136 workers of eight grain storages were exposed to dust concentrations ranging from < 0.2 and 275.4 mg/m³ which was beyond the WEL. The difference between our finding and previous studies might be because of small sample size among exposed workers.

Comparison of dust levels between different work settings

This study reported that there were significant differences in total inhalable dust concentration when compared between the two groups (furniture factory versus rice mill (p = 0.001); furniture factory versus sawmill (p = 0.001); non-exposed versus rice mill (p = 0.001); non-exposed versus sawmill (p = 0.001)). This shows that furniture factory emits low dust compared to rice mill and sawmill. Furthermore, most furniture factories in this study have separations between workstations with natural ventilation at the site. Whereas dust exposure in sawmill and rice mill industries were particularly high with sawmill depicting the highest median of total inhalable dust concentration. This was in contrast with a study in India among agricultural workers where they found that the highest value of dust exposure was recorded in the rice mills (GM = 8.2 mg/m^3, GSD = 1.5) (22). Another study (23) in Netherlands involving agricultural industry workers also found that inhalable total dust was the highest in the grain, legumes and seeds sector compared to agriculture and animal production sectors.

High dust emission could be due to several causal factors. Dewangan and Patil (22) highlighted that conventional method of processing and poor machine maintenance as contributing factors for dust emission in Indian rice mills. On the other hand, Ayalew and colleagues (24) stated that inadequate ventilation systems on top of limited working space might increase exposure level to wood dust. In addition to that, previous studies also revealed that dust exposure depends considerably on unit operations (22, 25 – 27). This might also explain the variations of dust concentration in the current study.

Lung function decline

Previous studies have shown that occupational exposure to various total amount and particle size of wood dust are associated with several disorders of all aerodigestive tracts such as chronic bronchitis and asthma (28). This can be seen in the decline of lung function. This study had shown that there were significant differences in measured FEV_1 (p = 0.001) and measured FEV_1/FVC among the workers (p = 0.001) with rice mill workers having the lowest median FEV_1/FVC. Predicted FEV_1/FVC also showed significant difference (p = 0.010) between the workers with sawmill workers having the lowest FEV_1/FVC (79%). Despite the significant difference, the predicted FEV_1/FVC values for all workers are within normal range (29). A previous study conducted to compare sawmill workers with control subjects had found significant difference in FVC, FEV_1 and PEF values (6). Ennin and colleagues (30) also discovered a significant difference in FVC, FEV_1, FER, PEFR and FEF25-75% between wood workers and control group. Besides, sawmill workers in India also showed a significant decline of FEV_1 and FVC value (31). The values of FVC among rice mill workers in India were lower relative to controls because they were impaired by symptoms such as chest tightness, cough and phlegm (1).

Two of the factors that will affect lung function values are gender (32 – 34) and smoking habits (35 – 37). Since the majority of workers are smoking male, further statistical test was performed in this study to control the factors of gender and smoking habit (Table V). It was discovered that FEV_1 (p = 0.001), measured FEV_1/FVC (p = 0.001), and predicted FEV_1/FVC (p = 0.010) showed significant differences among all workers. The relative decline in lung function may indicate that exposure to total inhalable dust might have affected workers' respiratory system.

Persistent exposure to dust causing lung function decline

This study has discovered a weak negative significant correlation between concentration of total inhalable dust with predicted FVC and FEV_1 but strong positive significant correlation with FEV_1/FVC which may suggest that constant exposure to high level of inhalable total dust may cause lung function decline. It has been known that the smaller the fraction size of the dust, the deeper it can go into the lungs and cause respiratory effects (38). This is in accordance to the previous studies conducted on lung function parameters decline among workers which are common in wood industry (39 – 41). In addition to that, the decline in lung function among wood workers are attributed to the inhaled higher concentration of total inhalable dust in the ambient air (30). On the other hand, moderate and positive strong correlation were shown for non-exposed group indicating that the concentration and lung function parameters move in tandem. It is expected that no lung function decline would be observed among non-exposed workers. However, in some cases lung function decline happened among perceived healthy non-exposed workers due to reasons such as previous diagnosis of tuberculosis which will cause the lung function to decline (42).

Limitation

This study was conducted only limited in Kelantan and Perak states in Peninsular Malaysia, hence the results cannot be generalised or represent other states in Malaysia since the exposure patterns might differ. Workers also refuse to participate justifying they felt uncomfortable wearing the sampling pump while working hence the small sample size. However, despites such limitations, this study has evaluated the inhalable dust exposure across different industrial settings and compare with the non-exposed subjects, then associate with the lung function decline.

CONCLUSION

Sawmill showed the highest total inhalable dust concentration followed by rice mill and furniture factory. Despite that, lung function decline shown in measured FEV_1 and FEV_1/FVC were prominently lowest among rice mill workers whereas sawmill workers had the lowest predicted FEV_1/FVC. Significant negative correlation was shown between lung function values with total inhalable dust concentration for exposed workers suggesting that relatively high dust concentration might affect respiratory systems of workers. In conclusion, despite dust concentration not exceeding the permissible limit, constant exposure might be the cause of the lung function decline among the exposed workers. For future research, it is recommended that more subjects should be recruited to generalise the study. On top of that, since more males work in the industries, the subject recruitment for the non-exposed group should be only among male workers to ensure the comparability between the workers in the industries and the non-exposed. Since both sawmill and rice mill workers were exposed to the highest total inhalable dust compared to others in this study, further study needs to be done to further investigate the organic dust that may contain aflatoxin or endotoxin. It may be useful to explore how the toxins will affect lung function and respiratory symptoms. Intervention study should also be conducted in the future to increase the knowledge and awareness among workers on health hazards because based on observations, most workers did not comply with the safety recommendations such as not wearing safety shoes and proper mask while working in dusty environment.

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